Temporal and spatial effects of fire on initial pathways of succession across the Yellowstone landscape

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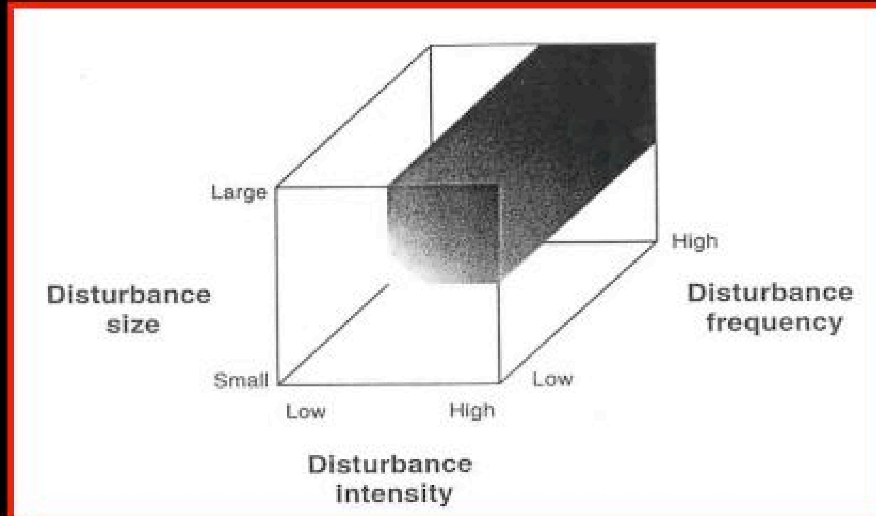
Context

Climate change is expected to alter the frequency and extent of disturbances such as fire. As a result, significant changes in vegetation patterns and carbon sequestration across forested landscapes may follow.

In considering potential impacts of climatically altered fire regimes, there is a need to better understand successional responses to spatial and temporal variation in disturbance regimes.

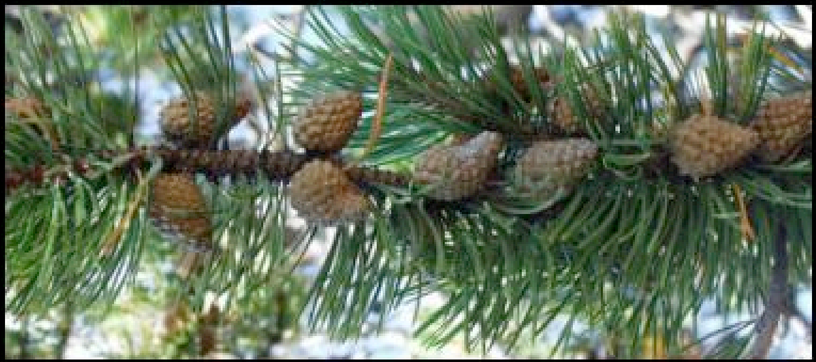
Disturbance regimes are characterized by disturbance size, intensity and frequency.



Turner, M. G. et al. 1998. *Ecosystems*, 1(6), 511-523

Understanding the influence of these disturbance components on propagule availability, in a spatially explicit manner, is an important step toward prediciting successional responses to variation in fire regimes.

In Yellowstone (YNP), the effects of fire size and intensity on propagule abundance have been well-quantified, and were controlled within my study, to better understand the effect of fire frequency on successional responses to the 1988 fires.



In Yellowstone, propagule availability is largely determined by patterns in stand-level percent serotiny.

Serotiny is a variable trait in inland lodgepole pine (*Pinus contorta* var *latifolia*); some individuals are serotinous while others are not.

Individuals that are serotinous carry these closed cones, which open when heated by fire, releasing almost a lifetime's worth of seed onto newly exposed mineral soil.

Therefore, in areas where serotiny is high, postfire seedling density is also very high.

In areas where serotiny is low, postfire seedling density is often very low.

However, those individuals that are serotinous, may not express this closed cone trait until later in life, making the timing of fire fundamental in predicting patterns of postfire succession.

Questions

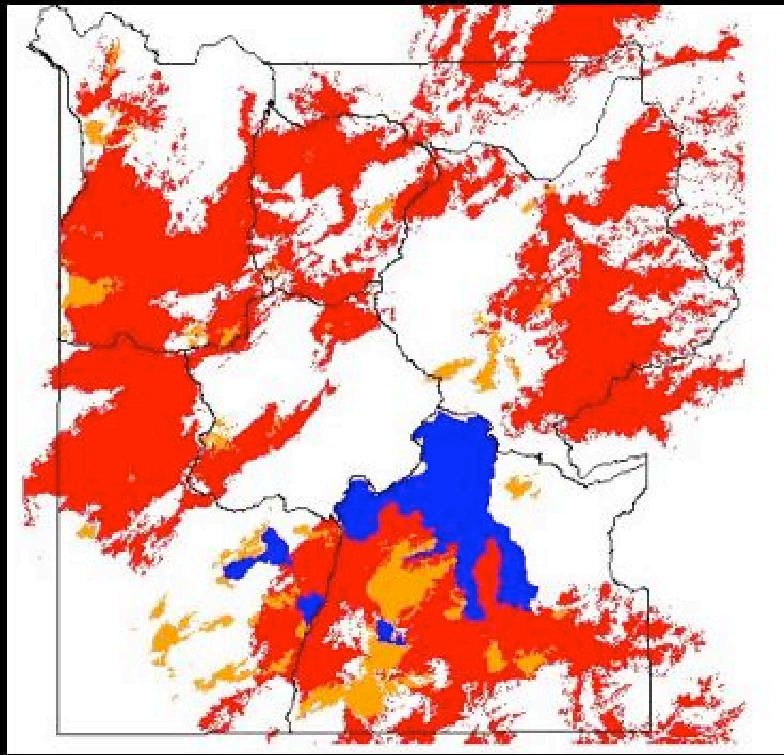
- Are there significantly different initial successional responses to different fire intervals (a proxy for fire frequency) across the Yellowstone landscape?

- What factors influence responses to temporal variation in disturbance regime?

Yellowstone is a fantastic place to examine the effects of fire frequency on succession.

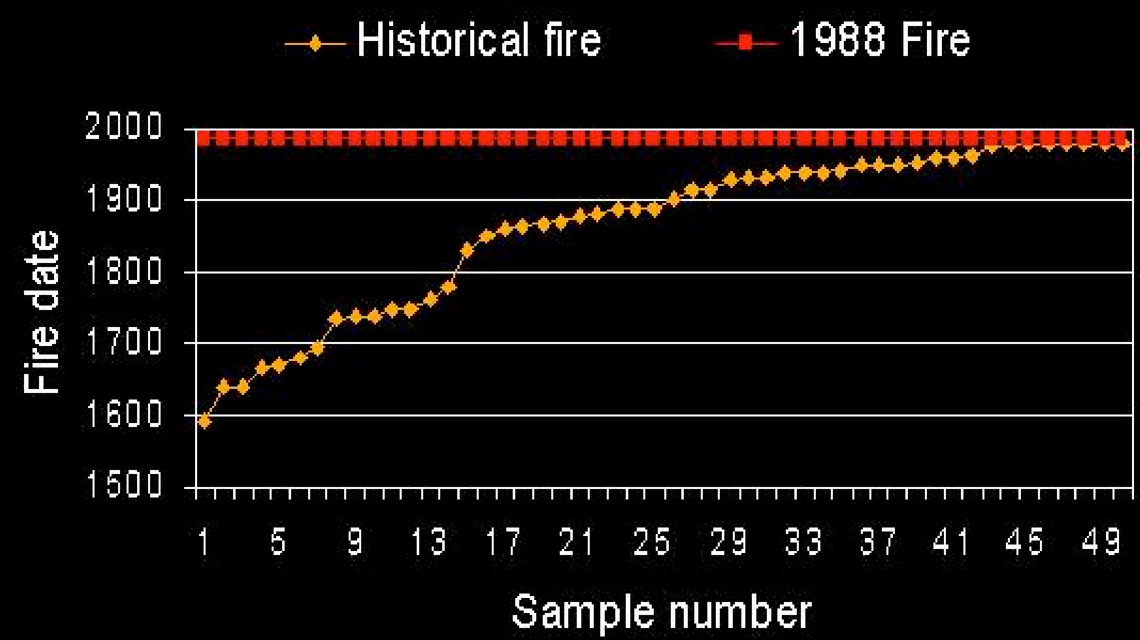
Not only is there an extensive spatially explicit database of historical fires, but a large portion of the park burned in 1988.

Therefore, it is possible to sample numerous sites that experienced different intervals between stand-replacing fires, but which all burned last in 1988.



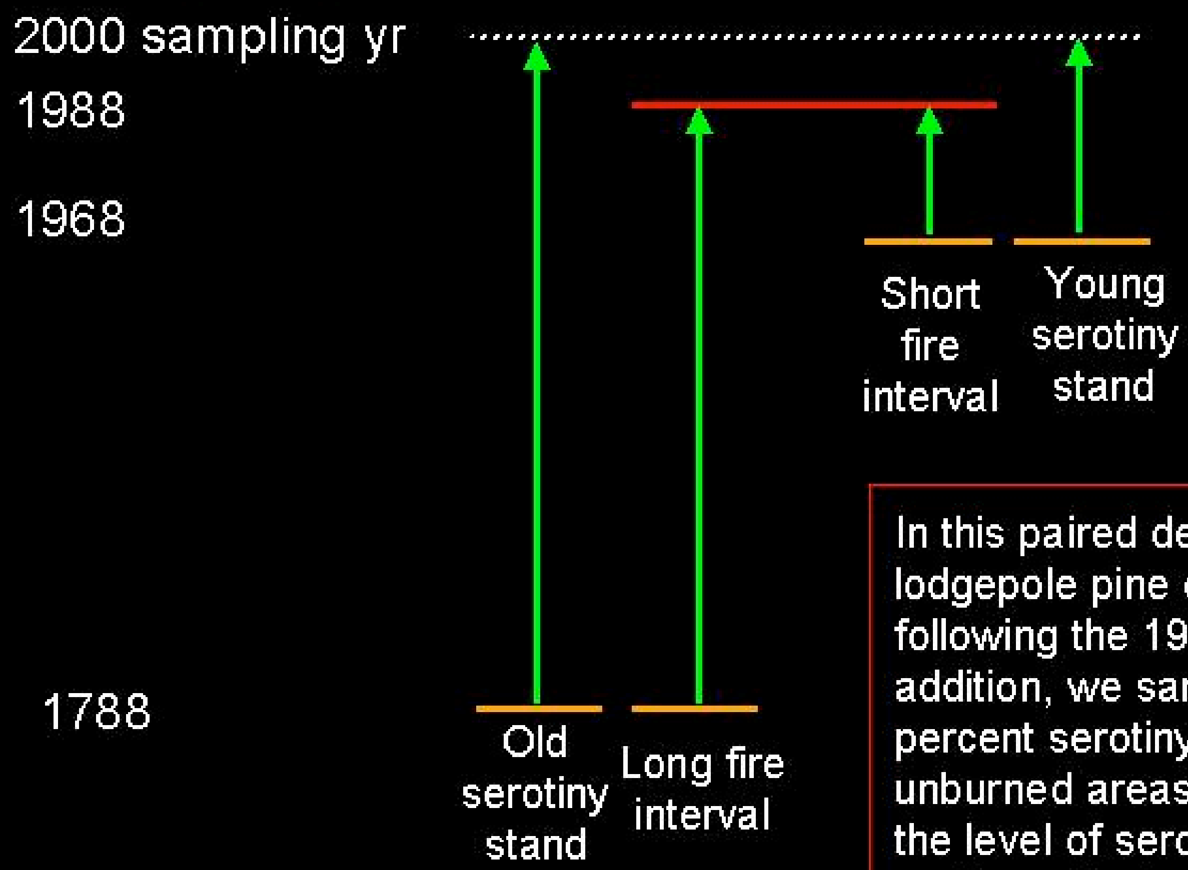
1988 fires

1880-1981 fires (from park records)



In a paired design, we sampled 25 “short fire interval” sites, which were derived from park fire records extending back about 100 years. Adjacent to each “short fire interval” site, we sampled a similar adjacent site of unknown interval. We cored trees to determine the stand origination date and therefore the fire interval, allowing us to extend our fire interval chronology back further in time. The 25 sites with a fire interval >100 years we call the “long fire interval” sites.

Sampling design:

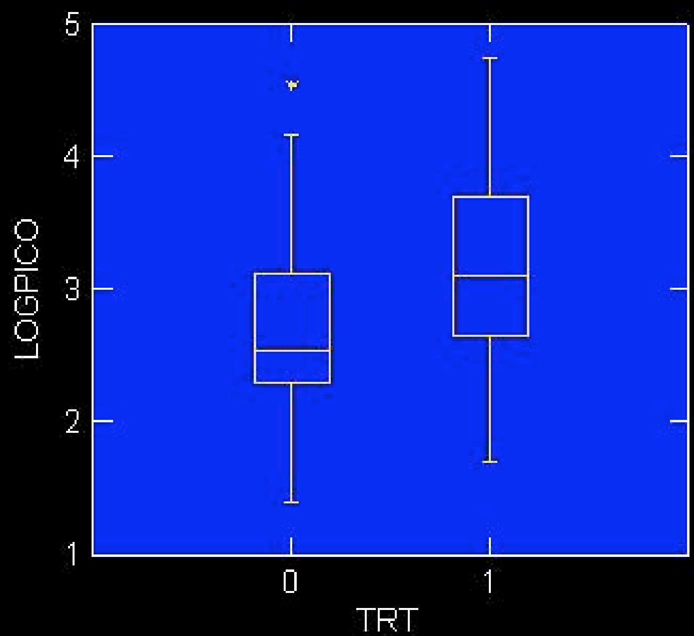


In this paired design we sampled lodgepole pine densities in 2000 following the 1988 fires. In addition, we sampled stand-level percent serotiny in adjacent unburned areas as a measure of the level of serotiny when the short and long fire interval sites burned in 1988.

Are there significant differences in initial successional responses to different fire intervals across the YNP landscape?

Paired t-test: $p < 0.001$

t-test: $p = 0.057$



Trt 0: 7- 119 yrs, n = 25
Trt 1: 100-395 yrs, n = 25

In a paired t-test, we see significant differences in log of lodgepole pine densities (logPICO) between the short (trt 0) and long (trt 1) fire intervals.

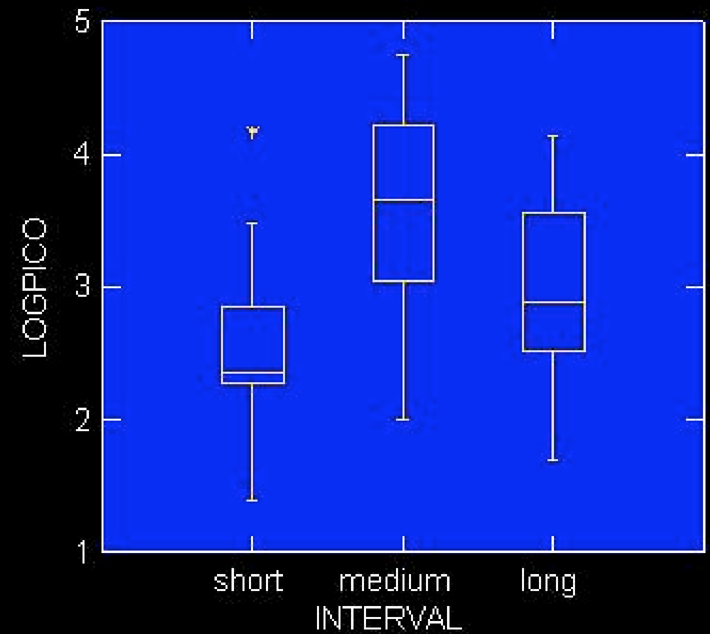
However, in an unpaired t-test, this difference is less significant, suggesting that there are broader-scale influences on lodgepole pine (PICO) density beyond plot level differences in fire interval.

Note that this is a log scale, so small changes can reflect orders of magnitude difference in postfire sapling densities.

ANOVA: $p < 0.001$

Additionally, when we reclassed the data into short, medium and long fire intervals, we detect a significant nonlinear relationship between fire interval and PICO densities.

What factors are controlling this nonlinear relationship?



Short : 7-50 yrs, n= 20
Medium: 51-160 yrs, n= 15
Long: 161-395 yrs, n = 15

What factors influence successional responses to temporal variation in disturbance regime?

Linear regression model:

Log(PICO) =	%serotiny	+ interval	- interval^2	- soil fertility	- slope
	0.0001	0.007	0.015	0.001	0.041

$R^2 = .596$, $F = 12.983$, $p < 0.001$

Variance in PICO density across the landscape is largely explained by percent serotiny and fire interval (which is only significant as a quadratic, reflecting the nonlinear relationship highlighted earlier).

What factors best explain patterns in serotiny?

Linear regression model:

ArcsinSqrt(%serotiny) = age – age*elevation

0.0001 0.0001

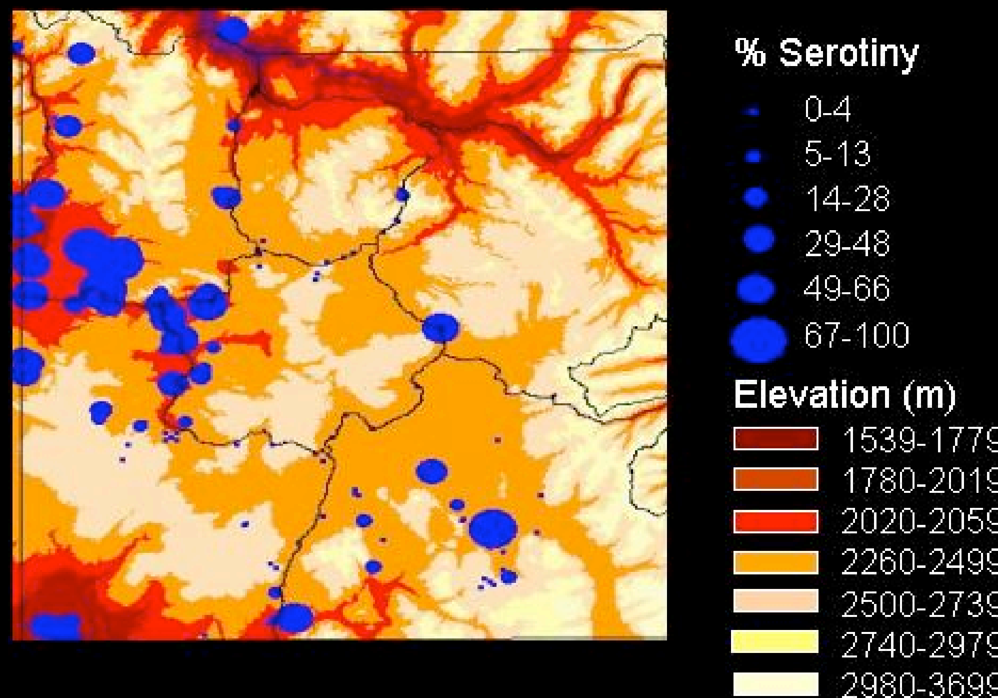
$r^2 = .528$, $F = 34.179$, $p < 0.001$

Variation in serotiny is best explained by age and a significant interaction term, age*elevation.

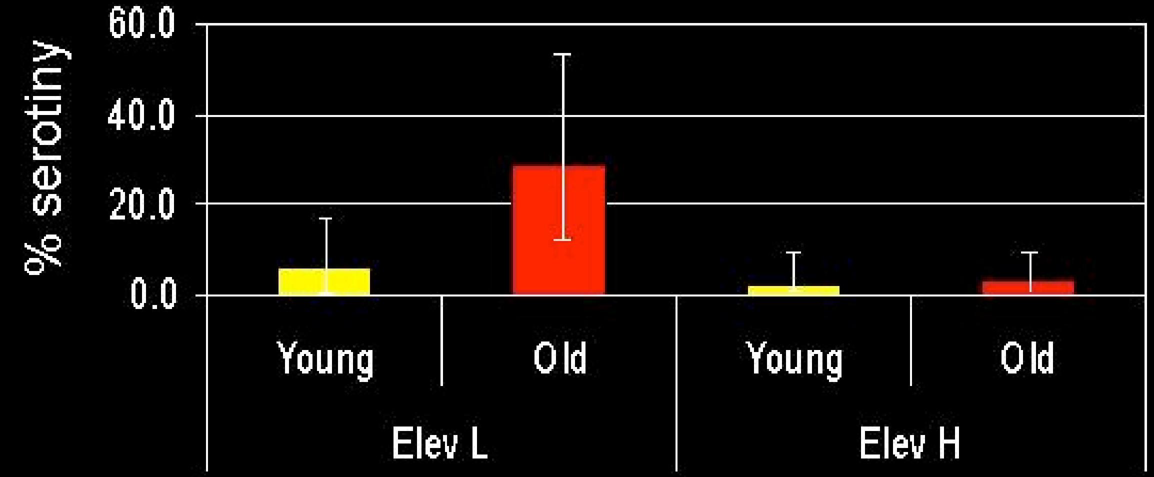
Therefore, the factor that most strongly predicts successional responses, varies both temporally and spatially, making both the timing and location of fires critical to predicting patterns of postfire succession.

Spatial variation in serotiny

Spatially, the highest levels of serotiny coincide with low elevation areas, whereas in higher elevation areas, serotiny is lowest.



Temporal variation in serotiny



In areas of high elevation, levels of serotiny generally are low and do not vary with stand age. However, in areas of high serotiny, there is significant temporal variation in serotiny between young and old stands.

Conclusions

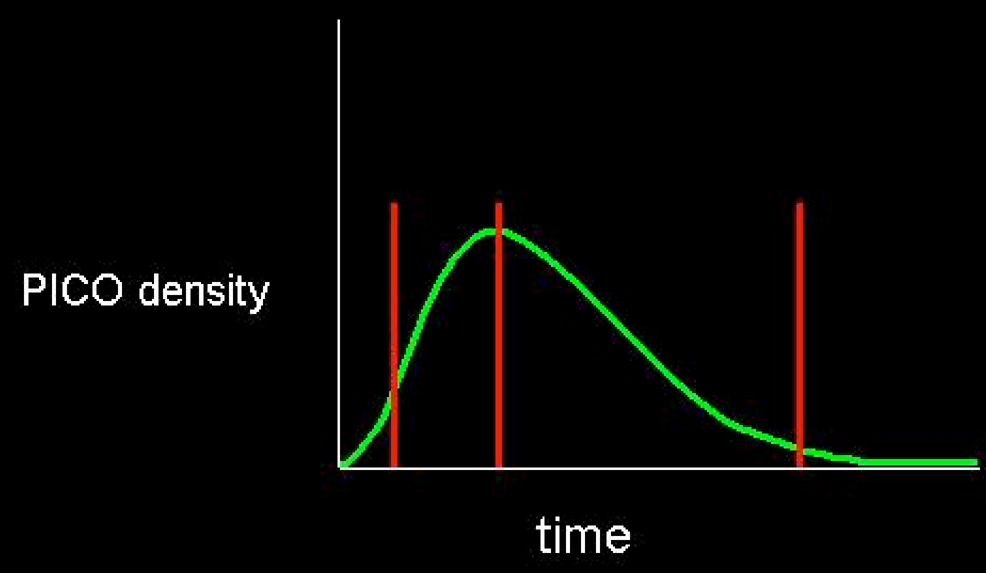
•Significant nonlinear relationship between fire interval and PICO density across the Yellowstone landscape.

•This relationship is governed primarily by the pattern of propagule availability (serotiny) across the landscape, which varies both spatially and temporally.

As a result:

In areas of low serotiny (high elevation):
Fire frequency is less important in predicting postfire succession.

In areas of high serotiny (low elevation):
Fire frequency very important in predicting postfire succession.



Therefore, the timing of fire can significantly influence postfire succession, due to the interaction of fire frequency with the spatial pattern of propagule adundance across the park.

Understanding the interaction of fire size, fire intensity and fire frequency on propagule abundance in a spatially explicit manner is a fundamental step toward understanding the effect of fire regimes on successional patterns.

This approach will be a powerful tool in predicting how climatically altered fire regimes may drive new patterns of succession across the Yellowstone landscape.

		↗ ?
fire regime → pattern → altered fire regime		
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The next step in my research will model patterns of succession and carbon sequestration in response to fire regimes under different climate scenarios in Yellowstone National Park.

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